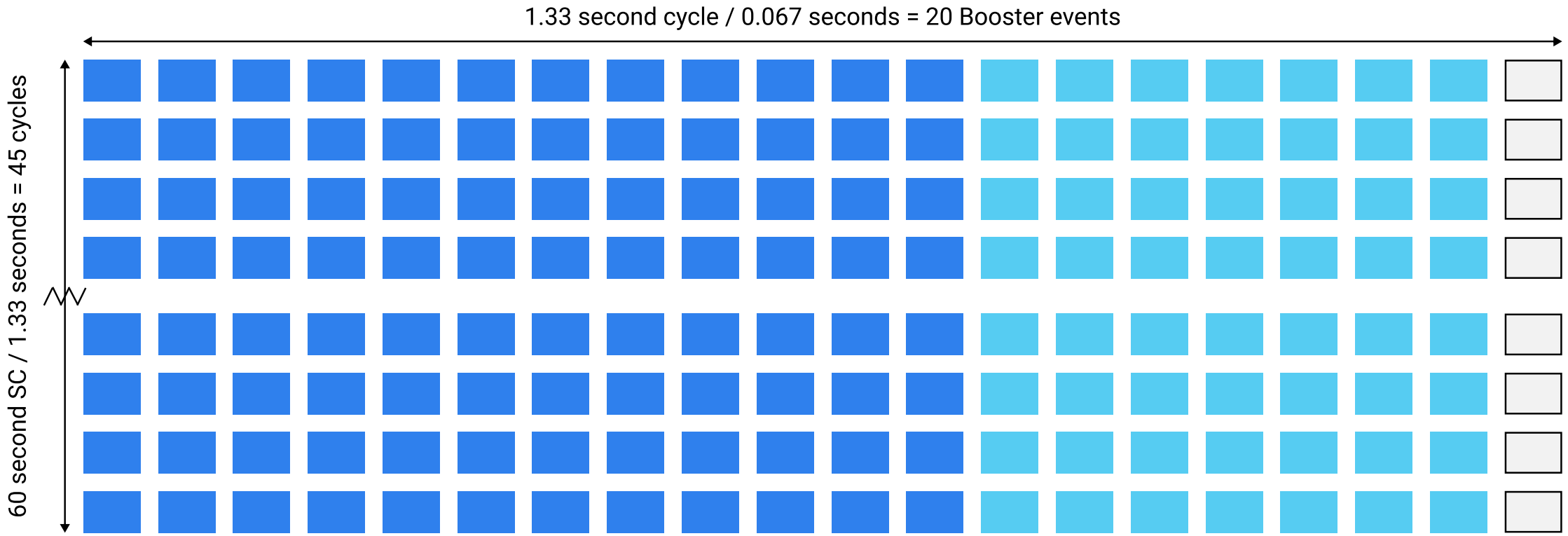
Timeline Event Placement

as it pertains to Booster batches and BNB spills

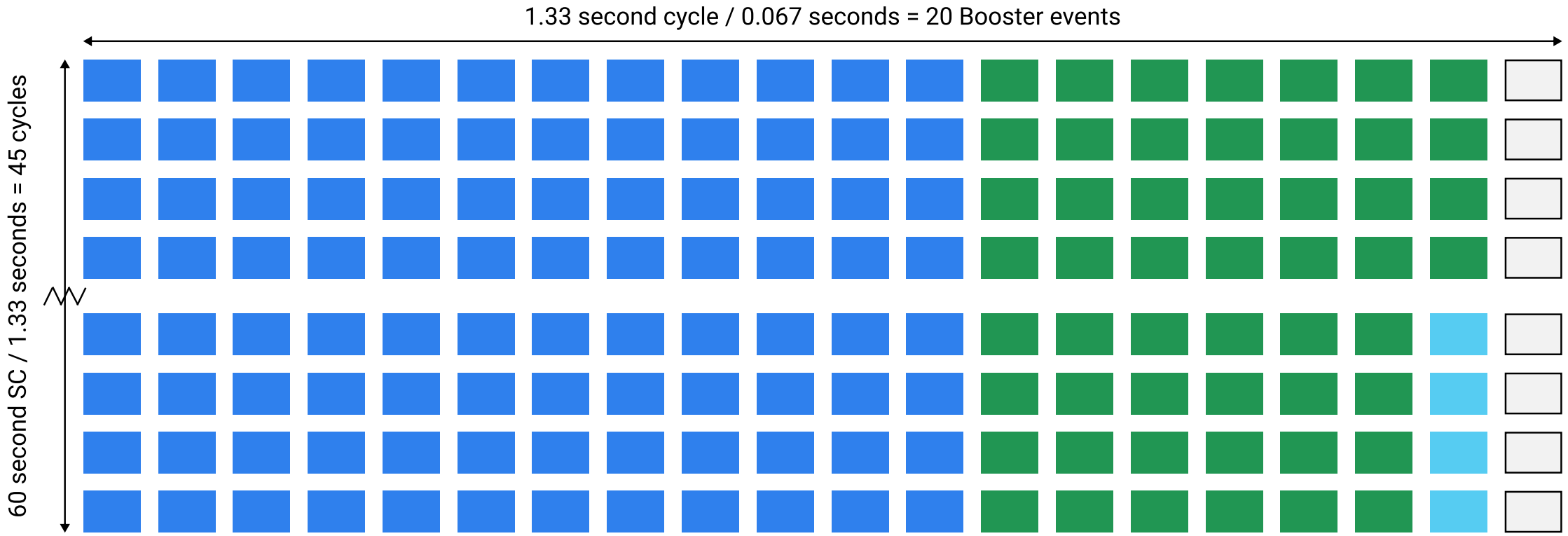
Alyssa R Miller 2020.03.27



(20 Booster events / cycle) * 45 cycles = 900 possible Booster batches / SC
(12 Booster batches / NuMI spill) * (45 spills / SC) = 540 $15s / SC
360 remaining Booster batches, filled by $11s and $12s

12 batch NuMI

$1D $15 $11 $1C $19 $13 $12

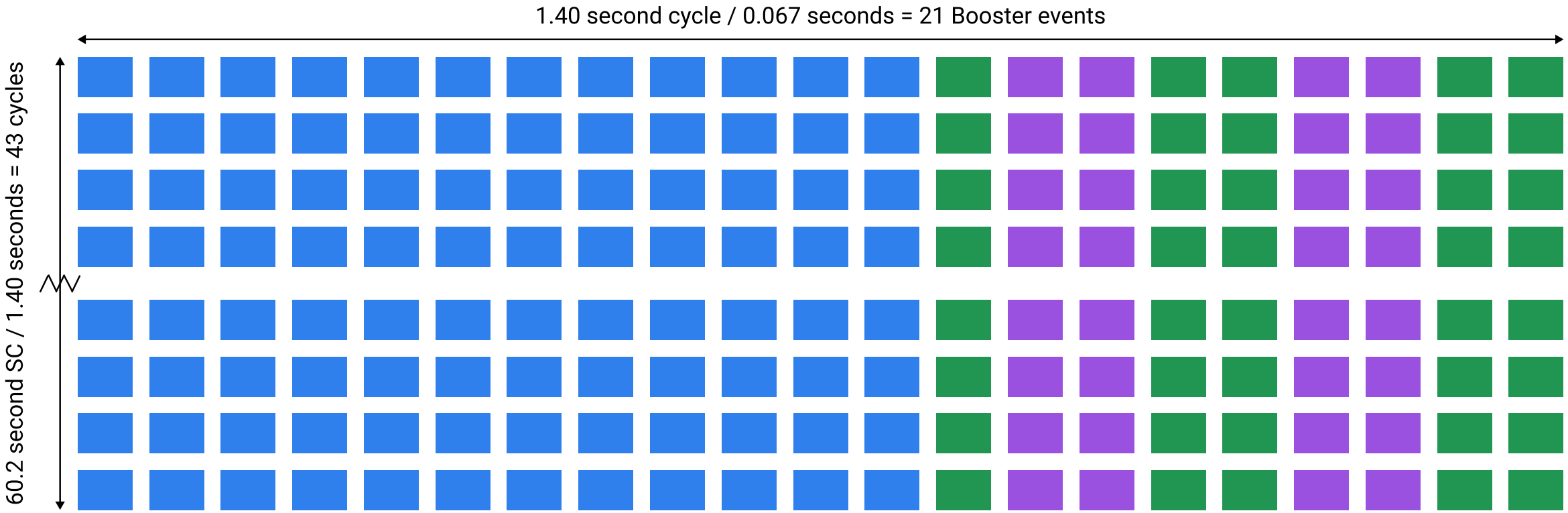


BNB requests 5 Hz spill rep rate (averaged over the SC):

(5 BNB spills / second) * 60 second SC = 300 $1Ds / SC
TLG optimizes even spacing of $1Ds: 300 $1Ds / 45 cycles = 6.66 $1Ds / cycle
TLG places 7 $1Ds / cycle for first 30 cycles
TLG places 6 $1Ds / cycle for last 15 cycles

12 batch NuMI + 5 Hz BNB

$1D $15 $11 $1C $19 $13 $12

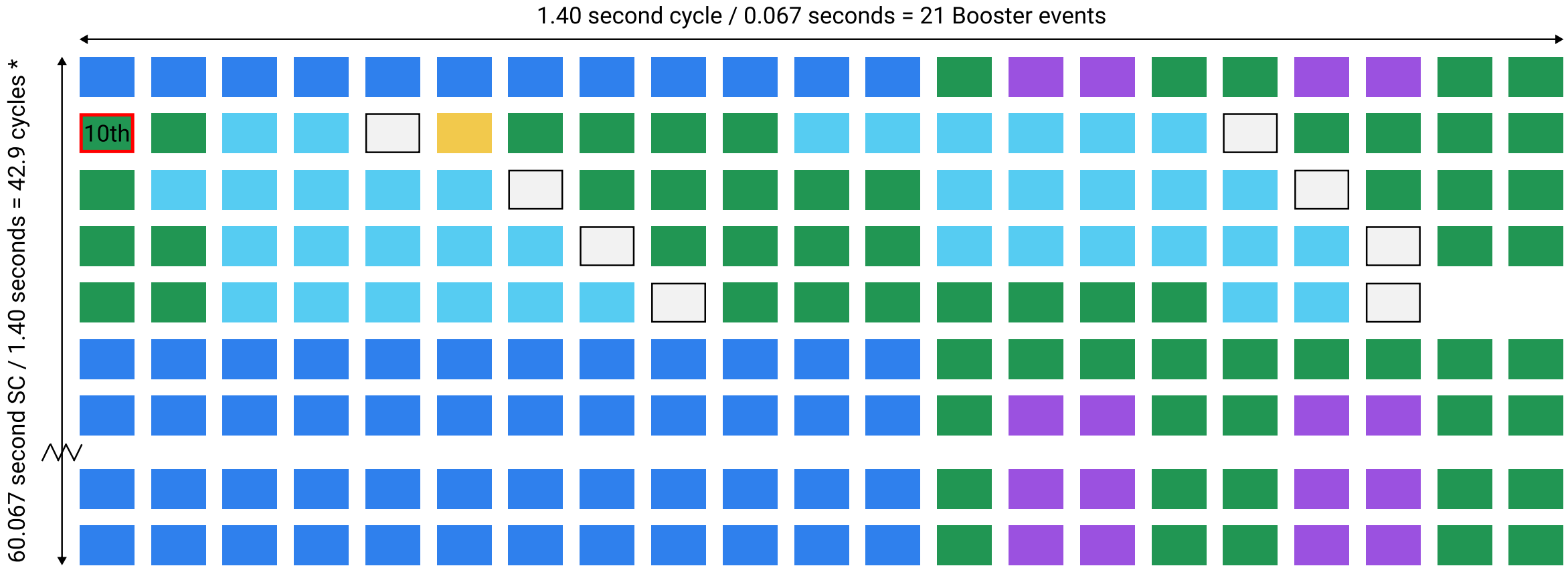


Running both NuMI and Muon Campus requires 1.4 second cycles. Two consecutive $1Cs are padded with with non-Recycler events to provide time for the Recycler RF to prepare.

BNB spills fill 215 remaining Booster batch spaces in SC, placing 5 BNB spills / cycle
This yields 3.57 Hz average BNB rep rate / 60.2 second SC

12 batch NuMI + max BNB (< 5 Hz) + 2x2 batch Muon Campus

$1D $15 $11 $1C $19 $13 $12

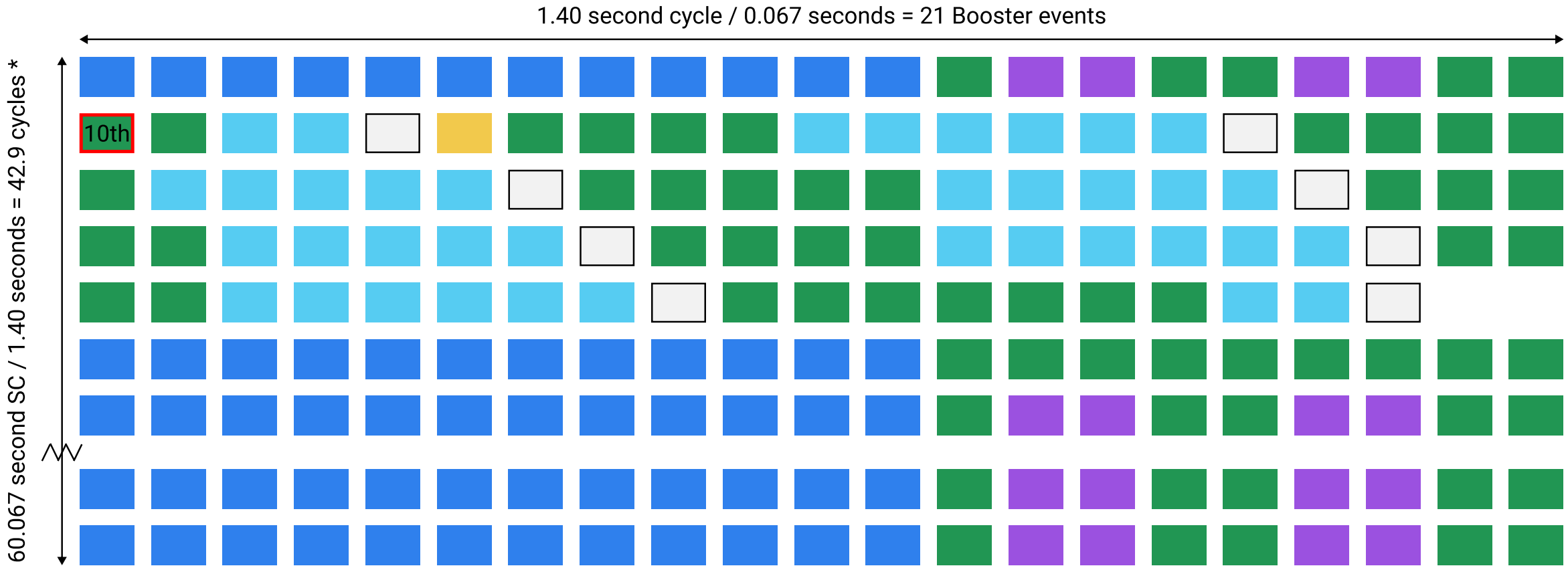


The Switchyard event takes up a 5.4 second long period of time for the slow spill process, which includes time for beamline devices to ramp up and ramp down. During this period, which includes but does not begin with the $13, BNB is the only beamline that can take beam.

To maintain the requested 5 Hz BNB average rep rate request, more $1Ds are filled in this period where there would have been NuMI and Muon Campus beam otherwise. The TLG also places $11s during the Switchyard event so that the 5 Hz BNB rate will not be surpassed for this 5.4 second period.

12 batch NuMI + max BNB (< 5 Hz) + 2x2 batch Muon Campus + Switchyard

$1D $15 $11 $1C $19 $13 $12

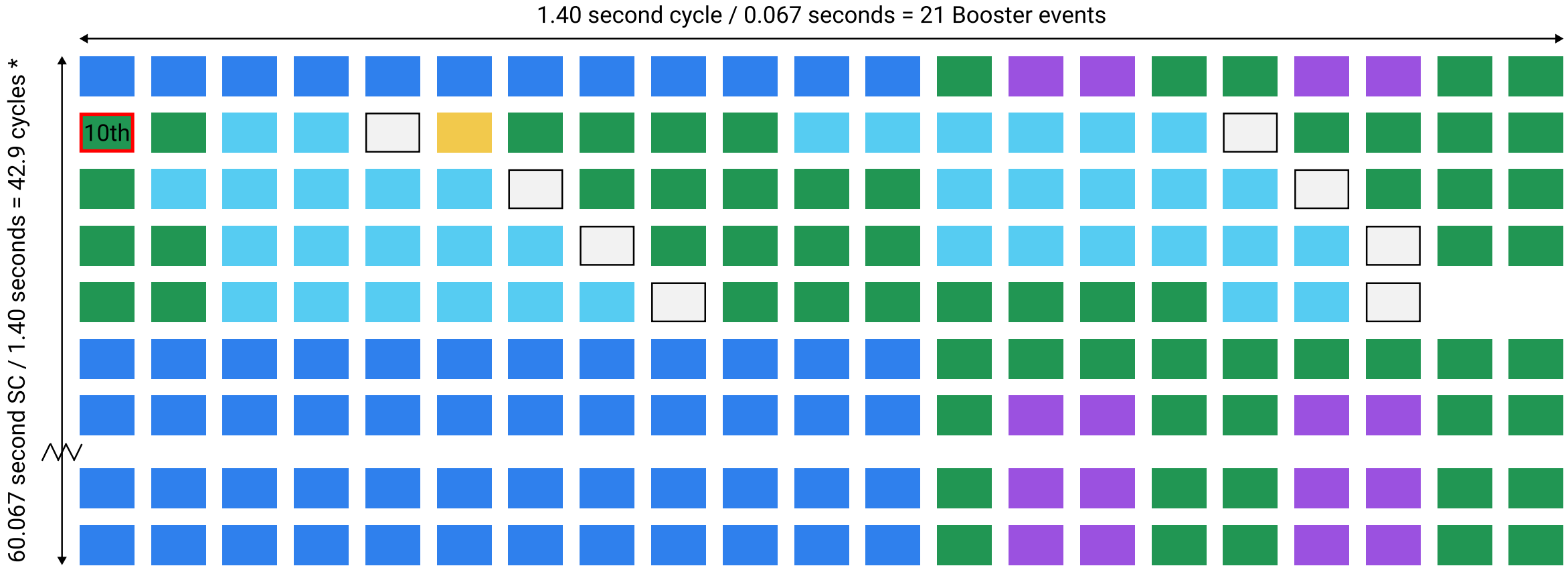


The Switchyard event causes the TLG to place BNB spills in atypical spots in the timeline (relative to NuMI spills), which creates an issue for MicroBooNE and other BNB experiments to come.

If the **10th Booster cycle to follow a train of $15s** is a $1D, MicroBooNE will see both BNB and NuMI beam in their detector simultaneously. MicroBooNE creates a veto window during the NuMI spill which overlaps with the acquisition window for that BNB spill (highlighted in red), which disallows them to use data from that event.

12 batch NuMI + max BNB (< 5 Hz) + 2x2 batch Muon Campus + Switchyard

$1D $15 $11 $1C $19 $13 $12

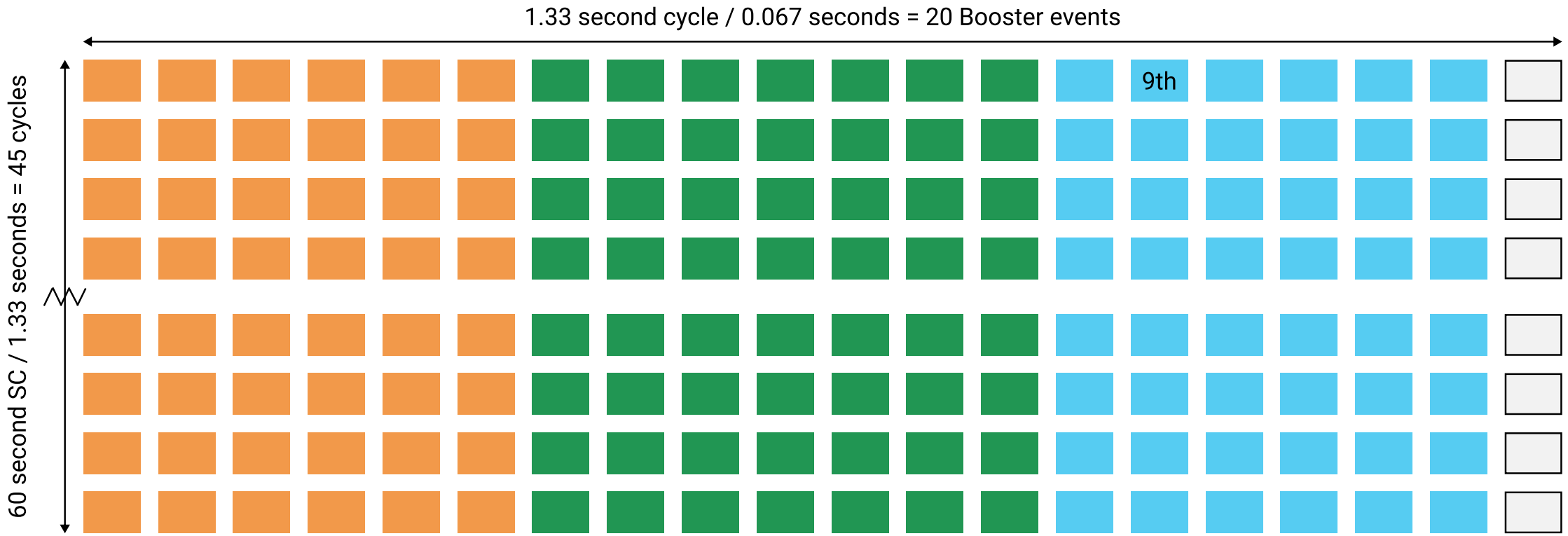


Due to the way the TLG automatically places them in the open spot during the Switchyard event, this 10th BNB spill cannot be eliminated without significantly reducing the total number of BNB spills per SC.

* SC is not defined by 1.40 (or 1.33) second increments, but it is helpful to visualize Booster batch placement this way. TLG optimizes Booster batch placement efficiency for each different beam destination request, but maintains a minimum 60 second long SC by convention. This drawing also shows two Booster batches “missing” in the timeline, but only for the sake of easy SC visualization.

12 batch NuMI + max BNB (< 5 Hz) + 2x2 batch Muon Campus + Switchyard

$1D $15 $11 $1C $19 $13 $12



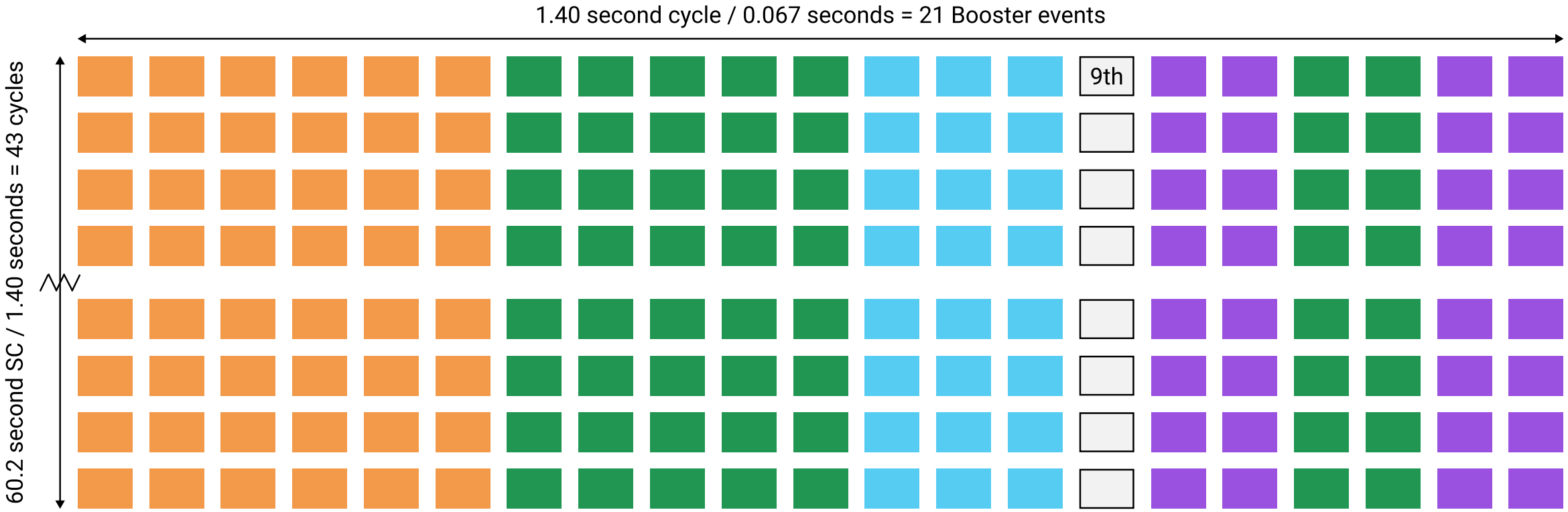
NuMI can only take 6 Booster batches at a time when Recycler is not operational
Muon Campus can't take beam without Recycler

BNB can easily take 5 Hz average rep rate

In this operational mode beam does not get manipulated by Recycler RF then transferred to Main Injector, so it is spilled into the NuMI beamline about one Booster cycle sooner (relative to the last $19 extracted from Booster), making the problematic BNB spill the 9th Booster batch to follow a train of NuMI batches.

6 batch NuMI + 5 Hz BNB

$1D $15 $11 $1C $19 $13 $12



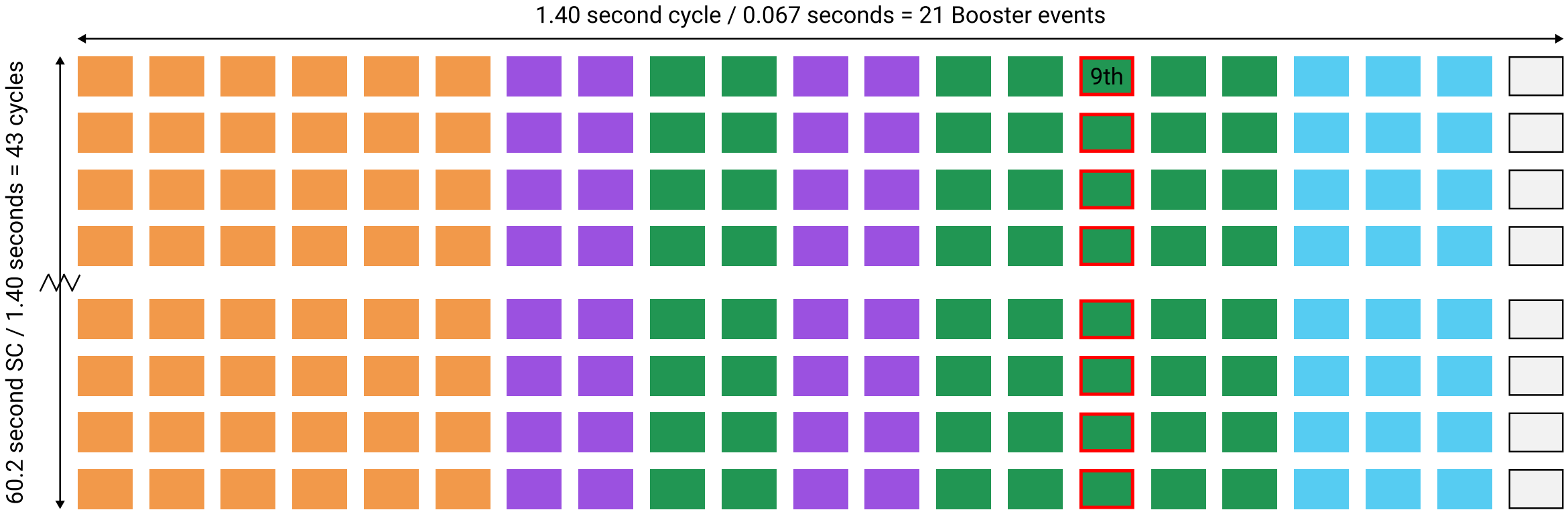
It is possible to run both NuMI in 6 batch mode through Main Injector only and Muon Campus in 2 batch mode through Recycler if Recycler is not yet tuned for slipstacking 12 batches to NuMI. This would most commonly follow a several month long shutdown period.

BNB can achieve 5 Hz average rep rate

In this operational mode the problematic BNB spill would still be the 9th Booster batch to follow a train of NuMI batches.

6 batch NuMI + 5 Hz BNB + 2x2 batch Muon Campus

$1D $15 $11 $1C $19 $13 $12



In the case of any deviation from an existing, pre-organized timeline (including but not limited to beam studies), BNB spills could be compromised. For example, $1Cs could be placed after a train of NuMI Booster batches instead of before them. In the case of any beam study, event placement isn't expected to be controlled.

Beam studies

$1D $15 $11 $1C $19 $13 $12

Credits

- Thanks to those who helped compile this information
  - John Kuharik (AD | Proton Source | Booster)
  - Mike Wren (AD | Operations)
  - Mike Olander (AD | Operations)